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Negative effects of strip conchotomy on intranasal air conditioning

Background and question

Surgery on the inferior turbinates is often performed routinely as a complementary procedure during functional nasal surgery. Over the past century, many different surgical techniques have been described to reduce the size of the turbinates [1]. A distinction is made

- 4thermal and radio frequency drive and
- 4surgical-resecting procedures.

Each technique has advantages and disadvantages. However, extensive resections of the inferior turbinate often lead to empty nose syndrome [1–3]. When selecting the preferred technique, the physiological functions of the inferior turbinates in the context of intranasal air conditioning must be considered. These include the regulation of respiratory resistance and thus the distribution of inhaled air across the nasal cross-section (diffuser), as well as enlargement of the mucosal surface area, reduction of nasal volume, formation of cleft spaces, humidification, and warming of the incoming air. Extensive resections of the nasal turbinates negatively affect all of these functions, as demonstrated in numerical simulations of intranasal air flow and air conditioning [4,5]. Radical operations on the nasal turbinates should now only be performed in

Neoplasias in this area [6].

Nevertheless, even today, the "strip conchotomy" is still performed, sometimes routinely, as part of functional nasal surgery. In addition to an increased risk of bleeding with severe crust formation and a prolonged healing process, this has negative effects on intranasal airflow and the conditioning of the inhaled air [7]. In this procedure, the inferior turbinate is first crushed and a strip of mucosa, including the mucous part of the turbinate head, is resected with septal scissors (Fig. 1 and 2). Depending on the extent of the resection, the caudal portions of the turbinal bone are also removed. The caudal mucosal and cavernous portions of the turbinate are resected independently. The popularity of this procedure is likely due to its rapid performance. However, its negative impact on the distribution of air in the nose is often overlooked.

To date, no numerical simulations using Computational Fluid Dynamics (CFD) have been published on nasal airflow, temperature, and humidity distribution after strip conchotomy.

The aim of this numerical study was to investigate the effects of a partial resection of the inferior turbinate in the sense of a strip conchotomy on nasal airflow, temperature and humidity distribution during a breathing cycle using CFD.

These are able to visualize the effects of turbinate resections on the flow dynamics in the nasal cavity [8–11]. For this purpose, a computed tomography (CT) scan of the paranasal sinuses of a patient who had undergone external unilateral partial resection of the inferior turbinate 2 years previously was used.

Study design and Examination methods

Model description

A three-dimensional virtual model of the nasal cavity and paranasal sinuses was constructed from this CT dataset of a patient with a unilateral strip conchotomy condition.

As in Fig. 3. As can be seen, the patient had undergone a partial resection of the inferior turbinate on the right side, including part of the turbinate head. The nasal septum was straight, and the remaining turbinates were of normal configuration. The mucosa showed no signs of chronic sinusitis. The CT scan was performed to rule out chronic sinusitis due to typical symptoms. The CT examination was performed on a Siemens Somatom Definition CT scanner (Siemens Healthcare GmbH, Erlangen, Germany) with a slice thickness of 0.6 mm.

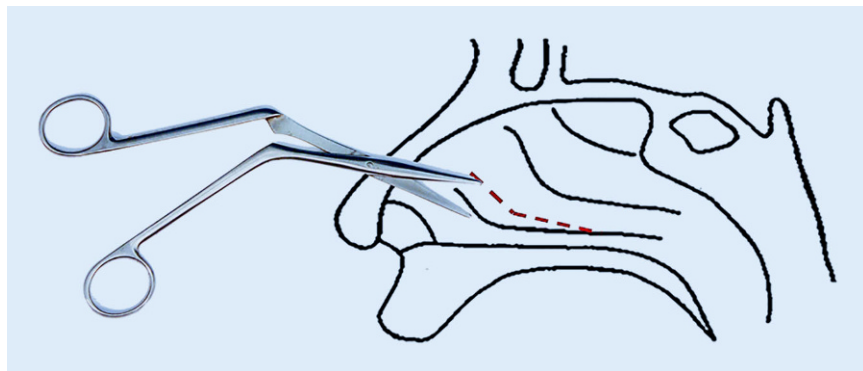


Fig. 18 Strip conchotomy with resection of the turbinate head and a strip of mucous membrane by scissors along the dotted line

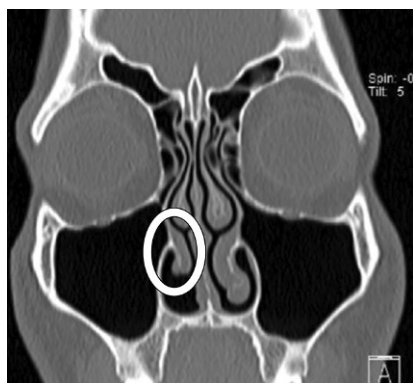


Fig. 38 Computed tomography scan of a patient with a condition following unilateral partial resection of the right inferior turbinate (white circle)

Software and model creation

The free, open-source software ITK-SNAP (v. 3.0.0) was used to segment the CT dataset. A virtual mesh with 3.1 million cells was generated around the surface model. Numerical simulation was performed using the CFD solver Fluent (ANSYS Workbench 14, ANSYS, Inc., Canonsburg, PA, USA).

The boundary conditions of the simulations were based on results from the authors' own in vivo measurements. Various static nasal airflow velocities were simulated and analyzed. The simulation was performed in a transient setting. Our own in vivo measurements served as the basis for the boundary conditions used in the virtual model.^{4,5} The respiratory cycle was defined by the inspiratory and expiratory pressure at the nasopharynx.

Inhaled air had a temperature of 20°C and 30% relative humidity, while exhaled air had a temperature of 37°C and 100% relative humidity. A complete breathing cycle lasted 4.2 seconds. Inspiration took 2 seconds, and expiration 2.2 seconds.

Results

The flow distribution, air temperature and humidity in the nasal cavity are shown by cross-sectional planes at 1.6 s at the end of inspiration (**Fig. 4**).

With regard to air velocity, a significant difference was observed between the non-operated left nasal cavity and the right one with partial resection of the inferior turbinate. On the left side, a homogeneous velocity distribution was found in the nasal cavity, with a moderate maximum velocity of up to 1.5 m/s. The right side showed a significantly increased velocity in a tube-like formation in the area of the former head and body of the inferior turbinate, with a velocity of up to 2 m/s. Furthermore, the flow velocity in the upper parts of the nasal cavity was significantly lower compared to the non-operated side. This tube-like airflow is still clearly visible in the nasopharyngeal region (**Fig. 4**, picture top right).

During inspiration, the mucous membrane of the lateral nasal wall and the nasal septum warms the incoming cool air. A clear

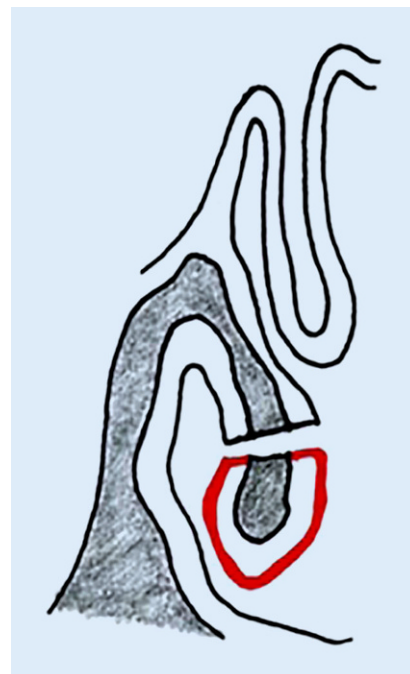


Fig. 28 Coronal schematic drawing of the resection area of a strip conchotomy (here including part of the os turbinale). (From [18], with kind permission of Georg Thieme Verlag, Stuttgart)

An increase in air temperature was observed near the nasal wall. The nasal turbinates are responsible for a large portion of heat exchange during inspiration. A significant difference in air temperature distribution was observed between the left, non-operated side and the right side with partial resection of the inferior turbinate, extending into the nasopharynx. The temperature increase along the inferior meatus was significantly smaller compared to the contralateral side. The cool center of the airflow was larger on the right side compared to the left side. This asymmetric temperature distribution was evident as far as the nasopharynx.

Almost identical to the measurements of air distribution and temperature, a significant difference in intranasal humidity was detected between the right and left nasal cavities. In the left nasal cavity, the airflow velocity was homogeneous, and the air temperature in the center of the airflow reached higher values.

and higher humidity levels were detected near the wall. On the right side, partial resection of the inferior turbinate resulted in a "tube-like" lower nasal passage. Airflow in this area is significantly faster, and the temperature is cooler in the center of the airflow. Additionally, the humidification of the inhaled air drops from nearly 100% to approximately 80%, which also has an impact in the nasopharyngeal region.

discussion

Chronic nasal breathing obstruction caused by a hypertrophic inferior turbinate can be treated by various techniques of turbinate plastic surgery [12]. Therefore, turbinate plastic surgery is a very frequently performed surgical procedure. It is often performed as part of functional nasal surgery.

Computational fluid dynamics is currently the only way to perform high-resolution analyses of flow, temperature, and humidity distribution in the nose. These simulations or approximations are based on computational models that have been standardly used in industry for many years. Numerous publications have demonstrated that their use in rhinology is feasible and delivers valid results [13–17].

The results presented here are the analysis of a virtual realistic model. The present case was selected because a unilateral strip conchotomy had been performed by an external ENT colleague, but otherwise the findings were approximately symmetrical, and a CT of the paranasal sinuses was available in addition to the evaluation of sinus symptoms. Despite being "only" one case, the numerical results are suitable for demonstrating the overall effects on nasal perfusion due to the symmetrical findings of the main nasal cavity.

How Fig. 5 shows, the right-sided strip conchotomy results in a visibly increased respiratory flow compared to the

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Negative effects of strip conchotomy on intranasal air conditioning

Summary

Goal. Partial resection of the caudal portion of the inferior turbinate, including the turbinate head, is still a common procedure in rhinosurgery ("strip conchotomy"). However, extensive resections of the turbinate impair nasal airflow and intranasal conditioning. The aim of this study was to determine the effect of partial resection of the inferior turbinate, including the turbinate head, on intranasal airflow, as well as on heating and humidification of the incoming air, using computational fluid dynamics.

Materials and methods. Based on a patient's computed tomography dataset, a bilateral realistic nasal model was created. Unilateral partial resection of the right inferior turbinate was performed externally, while the left inferior turbinate was preserved. Numerical simulations were performed to analyze intranasal airflow patterns, inspired air temperature, and humidity distribution.

Results. Due to the partial resection of the inferior turbinate on the right side, including the turbinate head, the flow pattern was significantly altered compared to the contralateral side. The resection resulted in a more centered and higher velocity in the inferior meatus, as well as reduced warming and humidification of the inspired air compared to the non-operated left nasal cavity.

Conclusion. The frequently performed partial resection of the caudal portion of the inferior turbinate can lead to impaired intranasal conditioning if extensive resection is performed. Therefore, this procedure should be avoided in rhinosurgery whenever possible, and a more mucosal-sparing approach should be chosen instead.

Keywords

Nasal turbinates · Surgical procedures · Nasal cavity · Nasal surgeries · Computer simulations

Negative effects of stripe conchotomy on intranasal conditioning

Abstract

Objective. Partial resection of the caudal part of the inferior turbinate including the head is still performed in rhinosurgery ("stripe conchotomy"). However, extensive resections of the turbinate affect nasal airflow and intranasal conditioning. The aim of this study was to determine the effect of partial resection of the inferior turbinate including its head on intranasal air flow as well as warming and humidification of the inspired air by means of computational fluid dynamics. **Materials and methods.** A bilateral, realistic nasal model was created based on the CT scan of a patient. A unilateral partial resection of the lower turbinate on the right side had been performed externally. A numerical simulation was performed to analyze intranasal air flow patterns, temperature, and humidity distribution of the inspired air.

Results. Due to the partial resection of the lower turbinate on the right side, the flow pattern was significantly altered compared to the opposite side. Resection leads to a centered and higher velocity in the inferior nasal meatus as well as to reduced heating and humidification of the inhaled air compared to the untouched left nasal cavity. **Conclusion.** Partial resection of the caudal part of the inferior turbinate may lead to disturbed intranasal conditioning of inspired air if performed too radically. Therefore, if possible, this procedure should be avoided and a more gentle mucosal procedure chosen.

Keywords

Turbinates · Surgical procedures, operative · Nasal cavity · Nasal surgical procedures · Computer simulation

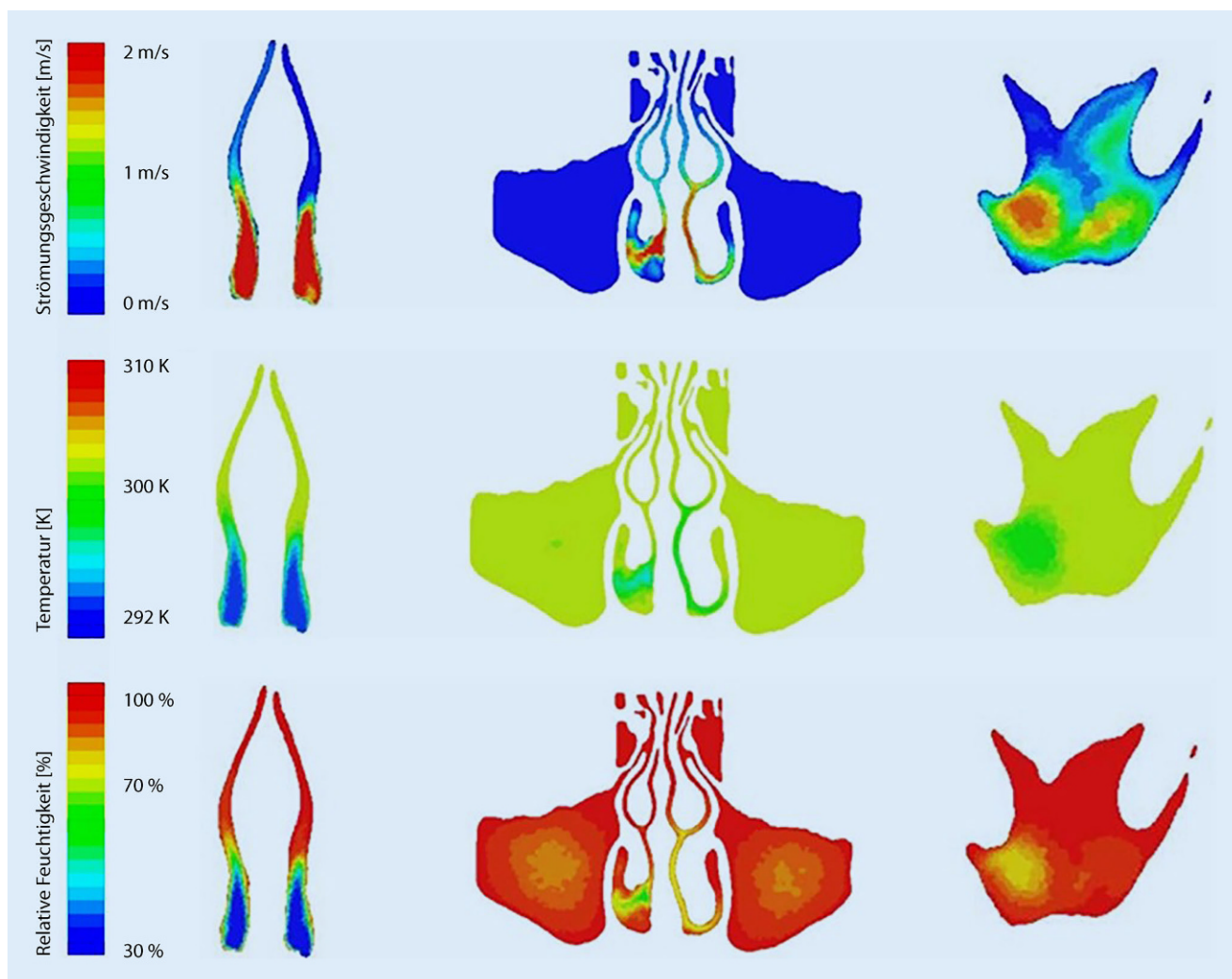


Fig. 48 Color-coded distribution of flow velocity, air temperature, and relative frequency along the nasal cavity using coronal slices (anterior to posterior)

In addition to creating a widened cleft space, the preservation of the physiological function of the nasal turbinates and their function (warming and humidifying the respiratory air) should be the main goal of turbinate surgery [18]. The balance between sufficient tissue reduction to relieve obstructive symptoms and sufficient preservation of mucosal tissue to prevent crusting and mucosal desiccation is a crucial prerequisite in turbinate surgery. Partial resection of the inferior turbinate, such as a strip conchotomy, not only reduces nasal inspiratory resistance but also improves the respi-

functional function of the nose, as large parts of the surface or mucous membrane of the turbinate are removed.

The nasal valve is a physiological constriction that is crucial for efficient humidification and warming of the inhaled air [4,5,8–10]. Hypertrophy of the lateral nasal wall and the inferior turbinate can lead to significant nasal obstruction. Grützmacher et al. demonstrated in various nasal models with varying degrees of resection that a partial reduction of the inferior and, if necessary, the middle turbinate can lead to a reduction in inspiratory resistance while still maintaining a physiological distribution of inspired air.

can, provided the resection is moderate [19]. Lindemann et al. showed that very extensive turbinate resections lead to disturbed intranasal airflow and thus the air conditioning function of the nose is fundamentally impaired [4,5,9,10,20].

In a clinical study by Tsakiropoulou et al., 57 patients who underwent partial inferior turbinate resection were examined [21]. Here, too, spot in vivo measurements revealed a decrease in temperature in the inferior and middle nasal conchae by 13 and 19%, respectively. However, there was no significant decrease in relative humidity, which would have been expected. Here, the absolute humidity would have had to be calculated, since

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ENT 5 • 2019 **377**

assessment

The authors believe that partial resection of the inferior turbinate with resection of the turbinate head as part of the nasal valve (strip conchotomy) is performed too frequently and significantly disrupts intranasal conditioning. If too much turbinate tissue is resected, this often leads to empty nose syndrome, which severely restricts nasal respiratory function. Due to the excessively reduced nasal resistance, the main airflow is redirected exclusively to the inferior meatus. The radical reduction of the inferior turbinate volume leads to a "tunnel-like" airflow, which significantly reduces air contact with the mucosa and leads to significantly lower temperature and humidity in the nasopharynx on the affected side. Since adequate air conditioning through the nose is required for breathing in the lower respiratory tract, strip conchotomy, especially when performed bilaterally, can have a negative impact on nasal physiology. In view of the presented numerical simulation results, strip conchotomy should not be performed to reduce the size of the turbinates. Instead, methods should be preferred that leave the mucosal surface as intact as possible and do not radically reduce the turbinate volume.

Conclusion for practice

- 4 Partial resection of the lower nasal valve with resection of the turbinate head significantly disrupts intranasal air conditioning.**
- 4 If nasal discharge is too reduced, resistance, the main air flow is redirected exclusively to the lower nasal passage.**
- 4 The "tunnel-like" air flow after strip conchotomy leads to reduced contact of air with the mucosa.**
- 4 This leads to reduced temperature and humidity in the nasopharynx of the affected side.**

4 Therefore, strip conchotomy should to reduce the nasal turbinates should not be performed.

4 Methods appear to be more suitable, in which the mucous membrane surface is left as intact as possible.

4 The shell volume should not be radically reduced.

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Compliance with ethical guidelines

Conflict of interest. F. Sommer, A.-S. Grossi, MO Scheithauer, TK Hoffmann, F. Stupp, HR Briner and J. Lindemann declare that no conflict of interest exists.

This article does not contain any studies on humans or animals conducted by the authors.

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